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that the rôle of nutrition is secondary in nuclear division; that more importance should be attached to the proportion of carbon compounds in the protoplasm and to tendencies transmitted from ancestral forms; and that the constant occurrence of two nuclei has more than a nutritive significance. Their fusion must be regarded as of a sexual nature because of the fusion of two energids into one; because the result of the fusion is a sporogonium as in the case of the ordinary egg; because nuclear fusion necessitates a reduction of chromosomes; and because the formation of gametes on the gametophore recalls exactly the transformation of sporangia into conidiophores and has the same cause.

The author believes that the nuclear fusion in asci and basidia really represents the sexual reproduction in the higher fungi, and that the fourth theory mentioned is the true one, viz., that the ascus is a true sporogonium in all species and is therefore sporophytic in its nature. He believes that the primitive ancestral phycomycete had a greater or less resemblance to *Myzocyttium vermicolum*. It possessed a thallus bearing sporangia, which, in his opinion, represented the sporophytic stage. The sporangia were very susceptible to external conditions. This was followed by a thallus bearing gametangia, the gametophyte; the fused gametes gave rise to the fertilized egg, which on germination produced a new sporangium or *sporogonium* with the characters of an ordinary sporangium, but with the doubled nuclei. This sporangium was but slightly susceptible to external conditions. The author believes that this point should be strongly insisted upon, that the ancestral type possessed two sorts of sporangia: the one responsive to environment has given rise, under the influence of aerial life, to the various types of conidiophores met with in the Ascomycetes; the other, of sexual origin, has been modified but little and has given rise to the ascus.

The author proposes a new classification of the Ascomycetes, based on the reproductive organs, in which the whole group is divided into two, the *Gamétangiées* and *Gamétophorées*. The first possesses functional gametangia and includes *Dipodascus* and *Eremascus*. In the second the gametangia, if present, are no longer functional, and their place is taken by gametophores.

About forty-five different types of Ascomycetes are described and figured in the major portion of the paper. One cannot but marvel that a single investigator could have found time to study all these forms in detail and with thoroughness. A most confusing use of terms makes the whole discussion difficult to follow.—ELIAS J. DURAND.

Algal-animal symbiosis.—KEEBLE,¹¹ continuing his interesting experimental investigation of the associations of unicellular algae with the low animals occurring on the larger seaweeds living between and just below the tide-limits on the north coast of France, now reports the occurrence of a unicellular brown alga in *Convoluta paradoxa*, a tubellarian. He had previously found a green *Chlamydomonas*—

¹¹ KEEBLE, F., The yellow-brown cells of *Convoluta paradoxa*. Quart. Journ. Micros. Sci. 52:431-479. 1908.

like alga in another species of *Convoluta*.¹² The color of the animal is due in part to orange-red glands in the superficial tissues, and in part to yellow-brown algal cells in the deeper tissues as well. The animals appear always to contain these yellow-brown cells, and in attempted cultures of the animals from the eggs, under conditions precluding infection by algae, the animals fail to develop. Furthermore, when older animals, already containing numerous yellow-brown cells, are kept in the dark, the yellow-brown cells disappear, apparently being gradually reduced to indigestible granular remnants. Such animals, again lighted, fail to develop further unless reinfected; then, however, they grow rapidly as soon as the new algae have sufficiently multiplied.

These facts indicate a dependence on the part of the animal upon its algal associates which may well be called parasitism, a degree of parasitism carried to the extreme of consuming the algae only when starvation impends, and under normal conditions falling far short of such destruction. In describing such an association as this, in which one animal becomes parasitic upon many much smaller algae inclosed within its own tissues, our usual vocabulary suffers strain, for words have to be used with altered meanings. Thus we should naturally speak of the animal being infected by the algae, and wonder how it is accomplished; but shall we speak of the infection of a parasite by its host? The relation of host and parasite in these tubellarians is like that of alga and fungus in lichens, the parasite incloses, lodges, and in time of hunger may ultimately devour its host. These convolutas secure their hosts by ingesting them with other food. The animal feeds voraciously on a varied diet. Apparently in these animals, as in many others, digestion of great quantities of food is less complete than when only smaller quantities are taken at once. The brown algae, if ingested in small quantity, are all digested and destroyed, but if the quantity of food is large, some cells escape digestion, entering the tissue of the animal and in a way becoming a part of it.

KEEBLE sees in the photosynthetic activity of these algal cells their value to the animals. The unicellular brown algae contain chromatophores in which there are two pigments: a yellow, quickly soluble in hot 90 per cent. alcohol and decomposed by hot water (fresh?), and a green, which resembles chlorophyll. The products of photosynthesis KEEBLE says he has not been able to determine, but he regards the fat globules in the cells as the form in which the photosynthate is temporarily stored. These fat globules he has seen migrating from the algal cells into the animal tissues, and their number is directly proportioned to the state of nutrition of the two organisms, being abundant in well-lighted animals immediately after being brought into the laboratory, decreasing under the somewhat unnatural conditions of the laboratory, and disappearing entirely if the cultures are placed in filtered (that is, food-free) sea water in the dark. The synthesis of food from CO_2 and H_2O within its own body, if unaccompanied by deleterious products, is of obvious advantage to an animal. Yet the advantage seems to be less in *Convoluta paradoxa* than the earlier studied *C. roscoffensis*. In the latter, the

¹² See review in BOT. GAZETTE 46:68. 1908.

animal presently ceases to take food from without, and is nourished entirely by its endophytic algae; in the former, the animal continues to feed throughout its lifetime. For some reason, the parasitism is less complete.

The benefit to an animal in association with a plant is much more obvious than the benefit accruing to the plant. It is customary among naturalists to conceive of every structure, every act, every situation, as useful or advantageous to the organism, or as having been useful or advantageous in the past. Many cases might be cited which stultify such a position, yet KEEBLE seeks to find some value to the independent alga in its association with a dependent animal, and believes that it consists in a "solution of the nitrogen problem—a successful method of obtaining large supplies of nitrogen." This is plausible, and adding a usable nitrogen compound, such as uric acid or potassium nitrate, in due proportions to the food-free filtered water of laboratory cultures, prolongs the life and prosperity of plant and animal alike. But as KEEBLE plainly indicates, this profits individuals, not the species. Ingested algae of a certain sort, escaping digestion and manured with animal wastes, multiply in the tissues of this small animal; they grow and prosper; but beyond the body of the individual animal they do not appear to spread. They do not infect the eggs; they do not escape from the body of convoluta before or after its death; they die with it. Each convoluta larva is separately and freshly "infected" by some of its food which it fails to digest. But although KEEBLE has failed to find the alga in its free form, he believes that it has one, and that the species is continued by those individuals which escape the convoluta. Indeed this belief is inevitable, if the ingested and surviving endophytes produce no successors.

I can do no better than quote KEEBLE's own vigorous summary. "The interpretation of the relation between yellow-brown cell and animal depends on the point of view: From that of the animal it is obligate parasitism. From that of the species 'infecting organism,' it is an insignificant episode, involving the loss of that, probably small, proportion of its numbers which are ingested. From that of the individual ingested yellow-brown cell, it is a solution of the nitrogen problem—a successful method of obtaining large supplies of nitrogen."

Obviously, then, to the species of alga there is no use in the association; to certain individuals, which apparently produce no successors, there may be some advantage. Even if there were no other, I suppose some persons would claim an advantage for the algae which escape digestion and survive in the body of the animal, on the hypothesis that life is better than death!

KEEBLE has not yet succeeded in finding the yellow-brown cells in the free state, in cultivating them free from the animal body, or in identifying them with any now known algae; yet he has no doubt of their being algae. There is little reason either to question his opinion or to doubt his ultimate success in cultivating and identifying them.

The theoretical value and interest of this paper is greatly enhanced by the skill and care of the author as experimenter, writer, and draftsman.—G. J. PEIRCE.